Circumstances Influencing the Efficiency of Dynamo-Electric Machines. By Profs. Edwin J. Houston and Elihu Thomson.

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During the recent competitive trials made at the Franklin Institute as to the relative efficiency of some different forms of Dynamo-Electric Machines, the authors having been entrusted with the work of determining the relations between the mechanical power consumed and the electric and thermic effects produced, took the opportunity thus afforded to make a careful study of many interesting circumstances which influence the efficiency of these machines.

It is proposed in the present paper to select from the many circumstances thus noticed, a few of the more interesting, reserving the others for a future consideration.

It will readily be understood from the comparatively new field in which we had been working, no reliable data of the electrical work of these machines having before been obtained, that difficulties constantly arose owing to necessary conditions of operation, and new developments as to the behavior of the machines under varied conditions, were constantly met.

A convenient arrangement of the particular circumstances we are about to discuss may be, 1st, Those affecting the internal work of the machine; 2d, Those affecting the external work, and 3d, The relations between the internal and external work.

The mechanical energy employed to give motion to a Dynamo-Electric Machine is expended in two ways, viz., 1st, In overcoming friction and the resistance of the air; and, 2d, In moving the armature of the machine through the magnetic field, the latter of course constituting solely the energy available for producing electrical current. The greatest amount of power expended in the first way was noticed to be about 17 per cent. of the total power employed. This expenditure was clearly traceable to the high speed required by the machine. The speed therefore required to properly operate a machine is an important factor in ascertaining its efficiency.

The above percentage of loss may not appear so great, but when it is compared with the total work done in the arc, as heat, constituting as it did in this particular instance over 50 per cent. of the latter, and about 33 per cent. of the total work of the circuit, its influence is not to be disregarded. In another instance the work consumed as friction was equal to about 80 per cent. of that appearing in the arc as heat, while in the Gramme machine experimented with, this percentage fell to 20 per cent. of that which appeared in the arc as heat, and was only about 7 per cent. of the total power consumed in driving the machine.

In regard to the second way in which mechanical energy is consumed, viz.: In overcoming the resistance necessary to move the armature through the magnetic field, or in other words, to produce electrical current, it must not be supposed that all this electrical work appears in the circuit of the machine, since a considerable portion is expended in producing what we term the local action of the machine, that is local circuits in the conducting masses of metal, other than the wire, composing the machine.

The following instances of the relation between the actual work of the circuit, and that expended in local action, will show that this latter is in no wise to be neglected. In one instance an amount of power somewhat more than double the total work of the circuit was thus expended. In this instance also it constituted more than five times the total amount of power utilized in the arc for the production of light. In another instance it constituted less than one-third the total work of the circuit, and somewhat more than one-half the work in the arc.

Of course work expended in local action is simply thrown away, since it adds only to the heating of the machine. And since the latter increases its electrical resistance, it is doubly injurious.

The local action of dynamo-electric machines is analogous to the local action of a battery, and is equally injurious in its effects upon the available current.

Again, in regard to the internal work of a machine, since all this is eventually reduced to heat in the machine, the temperature during running must continually rise until the loss by radiation and convection into the surrounding air, are eventually equal the production, and the machine will at last acquire a constant temperature. This temperature, however, will differ in different machines according to their construction, and to the power expended in producing the internal work, being, of course, higher when the power expended in producing the internal work is proportionally high.

If therefore a machine during running acquires a high temperature when a proper external resistance is employed, its efficiency will be low. But it should not be supposed that because a machine when run without external resistance, that is on short circuit, heats rapidly, that inefficiency is shown thereby. On the contrary, should a machine remain comparatively cool when a proper external resistance is employed, and heat greatly, when put on short circuit, these conditions should be regarded as an index of its efficiency.

As a rule the internal resistance of Dynamo Electric Machines is so low that to replace them by a battery, the latter, to possess an equal internal resistance, would have to be made of very large dimensions, so that the efficiency of Dynamo-Electric Machines, cannot be stated in terms of battery cells as ordinarily constructed.

In regard to the second division, viz., the external work of the machine, this may be applied in the production of light, heat, electrolysis, magnetism, &c.

Where it is desired to produce light, the external resistance is generally that of an arc formed between two carbon electrodes ; the resistance of the arc is therefore an important factor in determining the efficiency. To realize the greatest economy, the resistance of the arc should be low, but nevertheless should constitute the greater part of the entire circuit resistance.

In some of our measurements the resistance of the arc was surprisingly low, being in one instance .54 ohm., and in another .79 ohm. It was however in some instances as high as 3.18 ohms.

It may be noted as an interesting fact that where the greatest current was flowing, the resistance of the arc thereby produced was low. This is undoubtedly due to higher temperature and increased vaporization from the carbons. In this latter case also the greatest amount of light was produced.

The amount of work appearing in the arc as measured by the number of foot pounds equivalent thereto, is not necessarily an index of the lighting power. In two instances of measurement, the amount of energy thus appearing in the arc was equal, while the lighting powers were proportionately as three to four. This apparent anomaly is explained by considering the resistance of the arc, it being much less in the case in which the greater light was produced. The heat in this case being evolved in less space, the temperature of the carbons, and therefore their light-giving powers, was considerably increased.

A few remarks on the economical production of light from electrical current may not be out of place. The light emitted by an incandescent solid will increase as its temperature is increased. In the voltaic arc the limit to increase of temperature is in the too rapid vaporization of the carbon. Before this point is reached, however, the temperature is such that the light emitted is exceedingly intense. No reliable method of measuring the temperature of the arc has as yet been found.

A well known method of obtaining light from electrical currents is by constructing a resistance of some material such as platinum having a high fusing point and heated to incandescence by the passage of a current. When platinum is employed the limit to its increase of temperature is the fusing point of the platinum, which is unquestionably but a fraction of the temperature required to vaporize carbon. Were the falling off in the amount of light emitted merely proportional to the decrease in temperature, the method last described might be economical. Unfortunately however for this method, many facts show that the decrease in the light emitted, is far greater than the decrease of the temperature. Most solids may be heated to 1000° F., without practically emitting light. At 2000° F., the light emitted is such that the body is said to be at a bright red. At 4000° F., the amount of light will have increased far more than twice, probably as much as four times that emitted at 2000° F. It is reasonable to suppose that with a further increase of temperature, the same ratio of increase will be observed, the proportionate increase in luminous intensity far exceeding the increase in temperature.

It would therefore appear that the employment of a resistance of platinum or other similar substance, whose temperature of alteration of state as compared with that of carbon is low, must be far less economical than the employment of the arc itself, which as now produced has been estimated as about two or three times less expensive than gas.

Indeed it would seem that future improvements in obtaining light from electrical currents will rather be by the use of a sufficient resistance in the most limited space practicable, thereby obtaining in such space the highest possible temperature.

Perhaps the highest estimate that can be given of the efficiency of Dynamo-Electric-Machines as ordinarily used, is not over 50 per cent. Our measurements have not given more than 38 per cent. Future improvements may increase this proportion. Since the efficiency of an ordinary steam engine and boiler in utilizing the heat of the fuel is probably overestimated at 20 per cent., the apparent maximum percentage of heat that could be recovered from the current developed in a Dynamo-Electric-Machine, would be overestimated at 10 per cent. The economical heating of buildings by means of electricity may therefore be regarded as totally impracticable.

Attention has, long ago, been directed to the use of Dynamo-Electric Machines for the conveyance of power. Their employment for this purpose would indeed seem to be quite promising. Since in this case one machine is employed to produce electrical currents, to be reconverted into mechanical force by another machine, the question of economy rests in the perfection of the machines and in their relative resistances.

In respect to the relations that should exist between the external and internal work of Dynamo-Electric Machines, it will be found that the greatest efficiency will, of course, exist where the external work is much greater than the internal work, and this will be proportionately greater as the external resistance is greater. Our measurements gave in one instance the relaton of .82 ohm. of the arc to .49 ohm of the machine, a condition which indicates economy in working. The other extreme was found in an instance where the resistance of the arc was 1.98 ohms., while that of the machine was 4.60 ohms. a condition indicating wastefulness of power.

Stated Meeting, Nov. 15, 1878.

Present, 23 members.

Vice-President, Mr. E. K. Price, in the Chair.

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